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To Mr. F.J. Kee
Director of Research

LEACHING PERFORMANCE OF WATER EXTENDIBLE POLYMER SOLIDIFIED DECONTAMINATION WASTE FORMS

A.S. Williamson

Simulated decontamination solutions and evaporator concentrates were solidified with two water extendible polymers and the waste forms were evaluated for leaching resistance over two years. Products containing wastes at normal use chemical concentrations were not affected by the distilled water immersion and had low incremental leach rates and cumulative radionuclide releases. Waste forms containing high concentrations of chemicals deteriorated from the water immersion and generally had high cumulative releases of radionuclides. Both polymers were considered to have equal performance. Solidification with water extendible polymers is considered to be an acceptable conditioning treatment for the storage and disposal of aqueous reactor operating wastes of low and intermediate level activity.

Interest in the use of water extendible polymers for the solidification of aqueous radioactive wastes led to research being undertaken to determine the benefits, limitations, and acceptability of this treatment. Initial work with Ashland Chemical's water extendible polyester resin, Aropol WEP661-P, on both a laboratory and 200L scale was reported in Research Reports 77-489-K and C78-53-K. This led to more detailed studies using a Dow vinyl ester resin, Waste Binder 101, as well as the polyester resin. In this program pretreatment and processing requirements for a number of simulated decontamination wastes and evaporator concentrates (Appendix 3) were determined together with the physical characteristics and initial leaching resistance of the different waste forms. These data were presented in Research Report 81-57-H.

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The different waste forms have been subjected to the IAEA Leach Test, Intercomparison Method, for twenty four months and this report discusses their performance.

DISCUSSION

Most of the simulated decontamination solutions treated at the normal use chemical concentration were unaffected by the twenty four months immersion in distilled water. Slight blistering and development of a convoluted upper surface were found with Turco 4512/Ashland and Dow specimens and the Turco 4521A/Dow waste form. The Peroxcit/Ashland product had swollen to give about a 10% increase in volume. All waste forms containing concentrated chemical solutions showed surface deterioration in the form of blistering, swelling, cracking and/or softening of the surface.

In the first two to three days of leaching exposure the incremental leach rates of all normal concentration waste forms were relatively high. This was due to rapid elution of radionuclides from the open cells present on the upper surfaces of the products which are exposed to air during the curing period. Once these radionuclides had been removed the incremental leach rate of all samples declined rapidly as shown in Table 1, indicating penetration of the leachant into the polymer matrix was limited. Occasional incremental leach rate perturbations were observed at different times during the leaching exposure. These were attributed to erosion of the outer surface of the waste forms leading to an increase in accessibility to the leachant of the radionuclides below the original surface.

The solidified concentrated decontamination solutions exhibited similar incremental leach rate behaviour to the normal strength waste forms as shown in Table 2. However, they had greater leach rate fluctuations and much higher cumulative radionuclide releases during the exposure period than the normal strength products. These variations obviously result from the less satisfactory solidified products obtained from concentrated decontamination solutions and greater deterioration of the waste products by the distilled water immersion.

Leaching resistance variations between wastes of any type solidified with either of the water extendible polymers were minor and it is considered that both polymers are equal in performance.

Detailed incremental leach rate and cumulative radionuclide release data for the two year leaching period are tabulated in Appendix 1 and shown graphically in Appendix 2.

TABLE 1

LEACHING PERFORMANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS
(Normal Chemical Concentration)

Waste Type	Matrix	Incremental Leach Rate $cm.d^{-1}$			Cumulative Release %		
		1 day	12 months	24 months	1 day	12 months	24 months
Turco 4512	WEP661-P DOW101	1.2×10^{-3} 4.4×10^{-4}	2.6×10^{-5} 9.7×10^{-5}	7.0×10^{-5} 2.0×10^{-5}	.02 .01	1 1.02	1.88 1.42
Turco 4521A	WEP661-P DOW101	6.3×10^{-3} 2.2×10^{-4}	1.8×10^{-5} 4.2×10^{-5}	9.4×10^{-6} 3.8×10^{-5}	.12 .01	1.21 .52	1.39 .8
Turco 4306	WEP661-P DOW101	5.5×10^{-4} 2.4×10^{-3}	1.8×10^{-6} 9.1×10^{-5}	2.7×10^{-6} 5.6×10^{-4}	.01 .05	.07 1.06	.12 1.71
Peroxcit	WEP661-P DOW101	4.9×10^{-3} 1.2×10^{-3}	6.1×10^{-5} 6.9×10^{-5}	2.6×10^{-5} 8.7×10^{-6}	.1 .02	2.19 .8	2.35 1.09
Calgon	WEP661-P DOW101	1.6×10^{-4} 7.5×10^{-4}	3.8×10^{-6} 2.6×10^{-6}	9.7×10^{-6} 3.0×10^{-5}	.01 .01	.08 .07	.15 .16
Pickering Solution	WEP661-P DOW101	5.3×10^{-3} 2.2×10^{-4}	5.8×10^{-6} 2.6×10^{-5}	3.9×10^{-6} 8.9×10^{-5}	.1 .01	.29 .33	.34 .95
STPP	WEP661-P DOW101	2.3×10^{-3} 1.8×10^{-4}	5.6×10^{-5} 3.6×10^{-5}	2.9×10^{-5} 2.9×10^{-5}	.05 .01	1.87 .45	2.26 .68
Peroxide Bicarbonate	WEP661-P DOW101	3.1×10^{-2} 4.9×10^{-3}	1.4×10^{-5} 5.0×10^{-5}	1.08×10^{-5} 9.3×10^{-5}	.61 .1	1.24 .96	1.43 1.65
Alkaline $KMnO_4$	WEP661-P	2.3×10^{-3}	1.2×10^{-5}	2.7×10^{-5}	.04	.24	.6

Incremental Leach Rate (Rn) - $Rn = \frac{a_n / A_o}{(F/V)t_n}$

a_n = radioactivity leached during leachant renewal period

A_o = activity initially present in specimen

F = exposed surface area of specimen (cm^2)

V = volume of specimen(cm^3) t_n = days of leachant renewal period

TABLE 2

LEACHING PERFORMANCE OF SOLIDIFIED CONCENTRATED DECONTAMINATION SOLUTIONS

Waste Type	Matrix	Incremental Leach Rate $cm.d^{-1}$			Cumulative Release %		
		1 day	12 months	24 months	1 day	12 months	24 months
Turco 4306	WEP661-P DOW101	8.3×10^{-3} 1.4×10^{-2}	1.6×10^{-3} 9.3×10^{-5}	1.3×10^{-3} 5.7×10^{-5}	.16 .28	30.49 2.61	46.09 3.29
Peroxcit	WEP661-P	1.0×10^{-2}	6.7×10^{-6}	1.3×10^{-5}	.2	.7	.81
Calgon	WEP661-P DOW101	1.4×10^{-3} 1.2×10^{-3}	1.2×10^{-5} 1.5×10^{-4}	6.2×10^{-6} 1.0×10^{-4}	.03 .02	.49 1.14	.58 1.83
STPP	WEP661-P DOW101	9.0×10^{-3} 2.9×10^{-3}	6.1×10^{-5} 1.3×10^{-4}	6.2×10^{-5} 4.7×10^{-5}	.18 .06	3.33 2.14	4.04 2.93
Pickering Solution	WEP661-P DOW101	8.7×10^{-3} 4.2×10^{-4}	1.1×10^{-4} 8.6×10^{-4}	6.7×10^{-5} 2.7×10^{-4}	.17 .01	2.01 76.77	2.71 79.7
Peroxide Bicarbonate	WEP661-P	1.6×10^{-2}	3.9×10^{-4}	2.0×10^{-4}	.32	19.87	21.7

CONCLUSIONS

A two year study of the leaching resistance of simulated decontamination wastes solidified with water extendible polymers has been completed with the following results.

Products containing wastes at normal use chemical concentrations were relatively unaffected by the prolonged distilled water immersion. Incremental leach rates and cumulative radionuclide releases from these products were low. In contrast, waste forms containing high concentrations of chemicals suffered visible surface deterioration from the water immersion and in most cases had high cumulative radionuclide releases.

Variations in water and leaching resistance between wastes of any type solidified with either of the two water extendible polymers were minor and both polymers are considered to have equal performance.

Solidification with water extendible polymers is considered to be a suitable conditioning treatment for storage and disposal of aqueous reactor operating wastes of low and intermediate level activity. The chemical salt concentration of the wastes should not be higher than about 200 g/kg to obtain best performance from the waste form.

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APPENDIX 1

INCREMENTAL LEACH RATES AND CUMULATIVE RADIONUCLIDE RELEASES FROM SOLIDIFIED DECONTAMINATION SOLUTIONS

Waste: TURCO 4512

Ashland Aropol Wep 661-P
Sample Mass 103.9 g
Original Activity in μCi 18.0 ^{134}Cs 38.8 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	7.9	5.1	1.2×10^{-3}	.02
2	1.5	3.6	4.6×10^{-4}	.03
3	1.6	3.6	4.7×10^{-4}	.04
4	1.0	3.5	4.0×10^{-4}	.05
7	2.3	7.1	2.8×10^{-4}	.07
15	5.5	9.3	1.7×10^{-4}	.09
21	5.6	4.3	1.5×10^{-4}	.11
29	7.8	3.5	1.3×10^{-4}	.13
57	23.1	6.5	9.5×10^{-5}	.18
91	172.2	70.2	6.4×10^{-4}	.61
119	70.9	31.9	3.3×10^{-4}	.79
147	14.3	24.1	1.2×10^{-4}	.86
183	10.2	15.3	6.4×10^{-5}	.90
366	7.9	45.9	2.6×10^{-5}	1.00
633	23.2	400.2	1.4×10^{-4}	1.74
730	2.4	73.7	7.0×10^{-5}	1.88

Dow Waste Binder 101
Sample Mass 106.6 g
Original Activity in μCi 19.0 ^{134}Cs 41.1 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	1.2	4.0	4.4×10^{-4}	.01
2	4.3	9.1	1.1×10^{-3}	.03
3	2.6	7.5	8.6×10^{-4}	.05
4	1.7	5.8	6.4×10^{-4}	.06
7	3.0	7.0	2.8×10^{-4}	.08
15	6.9	14.8	2.3×10^{-4}	.11
21	16.9	33.0	7.0×10^{-4}	.20
29	11.6	21.5	3.5×10^{-4}	.25
57	14.2	28.0	1.3×10^{-4}	.32
91	23.4	45.0	1.7×10^{-4}	.44
119	14.6	35.2	1.5×10^{-4}	.52
147	13.4	33.9	1.4×10^{-4}	.60
183	17.0	32.9	1.2×10^{-4}	.68
366	43.6	162.5	9.7×10^{-5}	1.04
633	77.1	140.9	6.9×10^{-5}	1.38
730	9.2	14.0	2.0×10^{-5}	1.42

Waste: TURCO 4521A

Ashland Aropol Wep 661-P
Sample Mass 102.1 g
Original Activity in μCi 15.2 ^{134}Cs 36.4 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	16.5	47.2	6.3×10^{-3}	.12
2	3.3	8.0	1.1×10^{-3}	.15
3	1.5	4.4	5.8×10^{-4}	.16
4	1.6	6.3	7.8×10^{-4}	.17
7	4.1	14.5	6.1×10^{-4}	.21
15	62.2	178.0	3.0×10^{-3}	.67
21	18.7	57.6	1.3×10^{-3}	.82
29	14.3	29.0	5.3×10^{-4}	.91
57	14.5	13.9	1.0×10^{-4}	.96
91	14.3	17.4	9.2×10^{-5}	1.02
119	5.8	15.2	7.4×10^{-5}	1.06
147	4.3	17.4	7.7×10^{-5}	1.10
183	5.3	14.5	5.4×10^{-5}	1.14
366	4.7	29.4	1.8×10^{-5}	1.21
633	16.3	68.7	3.1×10^{-5}	1.37
730	1.0	8.2	9.4×10^{-6}	1.39

Dow Waste Binder 101
Sample Mass 105.6 g
Original Activity in μCi 16.2 ^{134}Cs 36.3 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	0.9	1.4	2.2×10^{-4}	.00
2	0.5	1.3	1.7×10^{-4}	.01
3	1.1	0.8	1.8×10^{-4}	.01
4	0.2	1.1	1.3×10^{-4}	.01
7	0.8	2.7	1.1×10^{-4}	.02
15	1.3	0.1	1.7×10^{-5}	.02
21	1.5	1.3	4.5×10^{-5}	.03
29	1.5	1.6	3.7×10^{-5}	.03
57	5.4	4.8	3.5×10^{-5}	.05
91	19.6	51.1	2.0×10^{-4}	.19
119	10.7	39.9	1.8×10^{-4}	.28
147	4.0	22.1	9.0×10^{-5}	.33
183	6.7	12.4	5.1×10^{-5}	.37
366	16.9	61.6	4.2×10^{-5}	.52
633	39.9	69.7	4.0×10^{-5}	.73
730	3.2	35.0	3.8×10^{-5}	.80

APPENDIX 1 (cont'd)

Waste: TURCO 4306

Ashland Aropol Wep 661-P
Sample Mass 103.9 g
Original Activity in μCi 11.2 ^{134}Cs 28.9 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	2.2	2.2	5.5×10^{-4}	.01
2	0.5	0.2	8.7×10^{-5}	.01
3	0.6	1.0	2.0×10^{-4}	.02
4	0.2	1.2	1.7×10^{-4}	.02
7	0.4	1.6	8.3×10^{-5}	.02
15	0.9	0.6	2.3×10^{-5}	.03
21	0.5	0.8	2.7×10^{-5}	.03
29	1.0	0.2	1.9×10^{-5}	.03
57	0.1	0.2	1.3×10^{-6}	.04
91	1.5	0.8	8.4×10^{-6}	.04
119	2.6	0.04	1.2×10^{-5}	.05
147	1.5	2.5	1.8×10^{-5}	.06
183	2.7	0.0	9.3×10^{-6}	.06
366	0.1	2.5	1.8×10^{-6}	.07
633	7.5	10.2	8.4×10^{-6}	.12
730	0.7	1.4	2.7×10^{-6}	.12

Dow Waste Binder 101
Sample Mass 106.2 g
Original Activity in μCi 11.3 ^{134}Cs 28.2 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	5.4	13.0	2.4×10^{-3}	.05
2	2.4	5.7	1.0×10^{-3}	.07
3	1.0	2.5	4.5×10^{-4}	.08
4	0.5	1.2	2.2×10^{-4}	.08
7	2.0	4.2	2.7×10^{-4}	.10
15	3.6	4.9	1.4×10^{-4}	.12
21	3.3	5.2	1.8×10^{-4}	.14
29	3.8	5.0	1.4×10^{-4}	.16
57	9.8	14.0	1.1×10^{-4}	.22
91	15.6	29.9	1.7×10^{-4}	.34
119	16.4	32.9	2.3×10^{-4}	.46
147	14.9	42.0	2.6×10^{-4}	.60
183	17.0	33.2	1.8×10^{-4}	.73
366	28.0	101.8	9.1×10^{-5}	1.06
633	46.5	171.5	1.1×10^{-4}	1.61
730	4.7	37.5	5.6×10^{-4}	1.71

Waste: PEROXCIT

Ashland Aropol Wep 661-P
Sample Mass 104.8 g
Original Activity in μCi 19.0 ^{134}Cs 47.2 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	14.8	48.6	4.9×10^{-3}	.10
2	4.1	7.8	9.2×10^{-4}	.11
3	1.9	5.8	5.9×10^{-4}	.13
4	1.5	3.8	4.1×10^{-4}	.13
7	4.3	10.4	3.8×10^{-4}	.16
15	11.4	21.9	3.2×10^{-4}	.21
21	8.7	18.1	3.4×10^{-4}	.25
29	18.4	48.4	6.4×10^{-4}	.35
57	64.3	111.3	4.8×10^{-4}	.61
91	42.1	95.9	3.1×10^{-4}	.82
119	29.9	104.9	3.7×10^{-4}	1.02
147	36.9	206.2	6.9×10^{-4}	1.39
183	59.6	323.2	8.2×10^{-4}	1.97
366	28.4	116.6	6.1×10^{-5}	2.19
633	48.3	23.1	2.1×10^{-5}	2.30
730	11.4	21.5	2.6×10^{-5}	2.35

Dow Waste Binder 101
Sample Mass 107.5 g
Original Activity in μCi 26.6 ^{134}Cs 41.9 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	4.0	12.1	1.2×10^{-3}	.02
2	2.0	2.5	3.3×10^{-4}	.03
3	0.7	1.4	1.6×10^{-4}	.03
4	0.6	2.2	2.1×10^{-4}	.04
7	1.0	4.7	1.4×10^{-4}	.05
15	6.2	10.0	1.5×10^{-4}	.07
21	7.6	9.2	2.1×10^{-4}	.09
29	15.4	26.6	3.9×10^{-4}	.16
57	20.0	31.2	1.4×10^{-4}	.23
91	22.2	38.4	1.3×10^{-4}	.32
119	17.5	35.7	1.4×10^{-4}	.40
147	16.5	37.9	1.4×10^{-4}	.48
183	19.3	34.4	1.1×10^{-4}	.55
366	40.1	129.3	6.9×10^{-5}	.80
633	79.8	109.9	5.3×10^{-5}	1.08
633	7.0	4.4	8.7×10^{-6}	1.09

APPENDIX 1 (cont'd)

Waste: CALGON

Ashland Aropol Wep 661-P
Sample Mass 100.3 g
Original Activity in μCi 21.5 ^{134}Cs 47.2 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d^{-1}	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	1.3	0.9	1.6×10^{-4}	.00
2	0.8	1.5	1.7×10^{-4}	.01
3	0.5	0.9	1.0×10^{-4}	.01
4	0.2	1.4	1.2×10^{-4}	.01
7	1.1	2.8	9.6×10^{-5}	.02
15	2.4	5.2	7.0×10^{-5}	.03
21	1.4	0.9	2.8×10^{-5}	.03
29	1.8	0.5	2.1×10^{-5}	.03
57	0.7	2.4	8.2×10^{-6}	.04
91	2.6	1.8	9.6×10^{-6}	.05
119	3.8	0.4	1.1×10^{-5}	.05
147	3.0	2.1	1.4×10^{-5}	.06
183	3.9	0.1	8.2×10^{-6}	.06
366	2.7	6.8	3.8×10^{-6}	.08
633	12.5	25.7	1.1×10^{-5}	.13
730	3.3	9.4	9.7×10^{-6}	.15

Dow Waste Binder 101
Sample Mass 103.6 g
Original Activity in μCi 23.3 ^{134}Cs 51.9 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d^{-1}	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	2.0	9.1	7.5×10^{-4}	.01
2	0.5	2.3	1.9×10^{-4}	.02
3	0.5	1.3	1.2×10^{-4}	.02
4	0.2	1.4	1.1×10^{-4}	.02
7	0.5	2.4	6.5×10^{-5}	.03
15	0.3	2.2	2.1×10^{-5}	.03
21	0.8	1.1	2.1×10^{-5}	.03
29	1.0	0.4	1.2×10^{-5}	.03
57	0.3	0.6	2.2×10^{-6}	.04
91	2.1	1.1	6.4×10^{-6}	.04
119	3.6	0.2	9.2×10^{-6}	.05
147	3.1	2.9	1.5×10^{-5}	.05
183	4.0	0.3	8.1×10^{-6}	.06
366	3.3	3.8	2.6×10^{-6}	.07
633	9.1	13.2	5.6×10^{-6}	.10
730	11.2	31.8	3.0×10^{-5}	.16

APPENDIX 1 (cont'd)

Waste: PICKERING SOLUTION

Ashland Aropol Wep 661-P
Sample Mass 102.6 g
Original Activity in μCi 23.8 ^{134}Cs 38.0 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	21.5	42.4	5.3×10^{-3}	.10
2	4.1	8.8	1.1×10^{-3}	.12
3	2.4	3.9	5.2×10^{-4}	.13
4	1.2	3.0	3.5×10^{-4}	.14
7	2.8	5.5	2.9×10^{-4}	.15
15	3.5	9.5	1.3×10^{-4}	.18
21	3.5	5.1	1.2×10^{-4}	.19
29	3.0	6.7	1.0×10^{-4}	.21
57	1.9	3.0	1.4×10^{-5}	.21
91	4.4	8.3	3.1×10^{-5}	.23
119	4.2	2.2	1.9×10^{-5}	.24
147	3.9	3.7	2.2×10^{-5}	.26
183	4.2	1.2	1.2×10^{-5}	.27
366	1.4	11.4	5.8×10^{-6}	.29
633	10.2	15.6	8.0×10^{-6}	.33
730	1.6	3.9	3.9×10^{-6}	.34

Dow Waste Binder 101
Sample Mass 105.1 g
Original Activity in μCi 50.1 ^{134}Cs 82.5 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	1.8	3.9	2.2×10^{-4}	.00
2	2.2	4.2	2.5×10^{-4}	.01
3	0.6	2.1	1.0×10^{-4}	.01
4	0.7	2.7	1.3×10^{-4}	.01
7	1.1	5.4	8.3×10^{-5}	.02
15	1.9	6.0	3.8×10^{-5}	.02
21	3.5	5.3	5.6×10^{-5}	.03
29	3.2	4.5	3.7×10^{-5}	.04
57	3.2	4.7	1.1×10^{-5}	.04
91	6.1	14.5	2.3×10^{-5}	.06
119	8.2	21.4	4.1×10^{-5}	.08
147	22.9	76.3	1.4×10^{-4}	.16
183	25.3	77.0	1.1×10^{-4}	.23
366	28.5	97.1	2.6×10^{-5}	.33
633	113.7	488.7	8.7×10^{-5}	.78
730	68.3	156 .8	8.9×10^{-5}	.95

APPENDIX 1 (cont'd)

Waste: STPP

Ashland Aropol Wep 661-P
Sample Mass 98.0 g
Original Activity in μCi 13.3 ^{134}Cs 26.7 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	1.8	16.6	2.3×10^{-3}	.05
2	1.7	0.7	3.1×10^{-4}	.05
3	1.1	0.0	1.4×10^{-4}	.05
4	1.3	1.4	3.4×10^{-4}	.06
7	5.1	1.4	2.8×10^{-4}	.08
15	17.9	4.4	3.6×10^{-4}	.13
21	26.1	2.7	6.1×10^{-4}	.21
29	46.0	2.7	7.8×10^{-4}	.33
57	107.0	233.3	1.5×10^{-3}	1.18
91	21.2	71.1	3.5×10^{-4}	1.41
119	10.9	39.4	2.3×10^{-4}	1.53
147	8.8	19.2	1.3×10^{-4}	1.60
183	8.4	16.0	8.6×10^{-5}	1.67
366	20.1	60.8	5.6×10^{-5}	1.87
633	42.6	93.2	6.5×10^{-5}	2.21
730	5.5	16.6	2.9×10^{-5}	2.26

Dow Waste Binder 101
Sample Mass 102.2 g
Original Activity in μCi 13.0 ^{134}Cs 26.4 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	0.8	2.1	1.8×10^{-4}	.01
2	1.1	1.5	2.2×10^{-4}	.01
3	0.7	0.1	1.0×10^{-4}	.02
4	0.2	1.3	1.9×10^{-4}	.02
7	0.7	2.8	1.5×10^{-4}	.03
15	2.0	3.5	8.9×10^{-5}	.04
21	3.0	1.8	1.0×10^{-4}	.05
29	3.2	1.1	6.9×10^{-5}	.07
57	0.6	4.4	2.3×10^{-5}	.08
91	7.1	4.9	4.6×10^{-5}	.11
119	3.8	7.9	5.4×10^{-5}	.14
147	5.9	23.3	1.3×10^{-4}	.21
183	7.5	35.2	1.5×10^{-4}	.32
366	8.2	42.5	3.6×10^{-5}	.45
633	21.6	48.2	3.4×10^{-5}	.63
730	6.0	15.6	2.9×10^{-5}	.68

APPENDIX 1 (cont'd)

Waste: PEROXIDE BICARBONATE

Ashland Aropol Wep 661-P
Sample Mass 97.6 g
Original Activity in μCi 20.4 ^{134}Cs 47.4 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	200.0	213.1	3.1×10^{-2}	.61
2	15.9	92.6	8.2×10^{-3}	.77
3	10.1	42.6	4.0×10^{-3}	.85
4	1.7	19.1	1.6×10^{-3}	.88
7	3.1	21.6	6.2×10^{-4}	.91
15	12.9	16.8	2.8×10^{-4}	.96
21	5.7	13.5	2.4×10^{-4}	.99
29	3.9	25.9	2.8×10^{-4}	1.03
57	2.6	49.0	1.4×10^{-4}	1.11
91	12.0	14.1	5.8×10^{-5}	1.14
119	9.1	3.7	3.4×10^{-5}	1.16
147	5.7	4.7	2.8×10^{-5}	1.18
183	8.3	1.7	2.1×10^{-5}	1.19
366	25.1	8.8	1.4×10^{-5}	1.24
633	103.6	9.8	3.2×10^{-5}	1.41
730	13.1	0.8	1.08×10^{-5}	1.43

Dow Waste Binder 101
Sample Mass 107.8 g
Original Activity in μCi 31.0 ^{134}Cs 78.5 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	30.4	75.7	4.9×10^{-3}	.10
2	6.7	18.8	1.2×10^{-3}	.12
3	3.6	11.6	7.1×10^{-4}	.13
4	4.6	6.8	5.3×10^{-4}	.14
7	17.2	9.9	4.2×10^{-4}	.17
15	35.6	30.3	3.8×10^{-4}	.23
21	35.2	16.3	4.0×10^{-4}	.28
29	38.5	11.3	2.9×10^{-4}	.32
57	113.7	27.4	2.3×10^{-4}	.45
91	103.0	39.9	2.0×10^{-4}	.58
119	64.1	27.6	1.5×10^{-4}	.67
147	35.8	34.3	1.2×10^{-4}	.73
183	32.8	18.8	6.7×10^{-5}	.78
366	116.1	82.1	5.0×10^{-5}	.96
633	435.3	129.7	9.8×10^{-5}	1.47
730	150.8	43.4	9.3×10^{-5}	1.65

APPENDIX 1 (cont'd)

Waste: ALKALINE PERMANGANATE

Ashland Aropol Wep 661-P
Sample Mass 94.5 g
Original Activity in μCi 38.3 ^{134}Cs 93.5 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134} Cs	^{60} Co		
1	29.6	29.4	2.3×10^{-3}	.04
2	3.8	6.0	3.8×10^{-4}	.05
3	1.4	6.7	3.1×10^{-4}	.06
4	2.2	5.3	2.9×10^{-4}	.06
7	8.9	19.9	3.7×10^{-4}	.09
15	17.6	26.0	2.1×10^{-4}	.12
21	6.9	9.4	1.1×10^{-4}	.13
29	6.9	5.6	6.0×10^{-5}	.14
57	9.3	14.3	3.3×10^{-5}	.16
91	12.8	14.1	3.1×10^{-5}	.18
119	2.8	8.9	1.6×10^{-5}	.19
147	2.1	.2	1.1×10^{-5}	.19
183	1.9	3.5	5.8×10^{-6}	.20
366	21.4	36.4	1.2×10^{-5}	.24
633	117.5	285.3	5.8×10^{-5}	.55
730	17.3	51.3	2.7×10^{-5}	.60

Dow Waste Binder 101
Sample Mass g
Original Activity in μCi ^{134}Cs ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134} Cs	^{60} Co		
1				
2				
3				
4				
7				
15				
21				
29				
57				
91				
119				
147				
183				

APPENDIX 1 (cont'd)

Waste: TURCO 4521A (conc)

Ashland Aropol Wep 661-P
Sample Mass 108.7 g
Original Activity in µCi 30.5 ^{134}Cs 77.0 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	19.9	88.7	5.1×10^{-3}	.10
2	2.4	6.3	6.5×10^{-5}	.11
3	2.0	4.4	3.0×10^{-4}	.12
4	1.5	3.1	2.2×10^{-4}	.12
7	3.0	4.6	1.2×10^{-4}	.13
15	4.1	5.4	5.6×10^{-5}	.14
21	4.0	5.0	7.1×10^{-5}	.14
29	5.2	6.5	6.9×10^{-5}	.15
57	14.7	20.3	5.9×10^{-5}	.19
91	18.9	27.1	6.4×10^{-5}	.23
119	11.8	15.0	4.5×10^{-5}	.25
147	8.5	14.5	3.9×10^{-5}	.28
183	11.4	11.6	3.0×10^{-5}	.30
366	30.6	34.9	1.7×10^{-5}	.36
633	132.1	136.9	4.8×10^{-5}	.61
730	27.8	12.2	2.0×10^{-5}	.65

Dow Waste Binder 101
Sample Mass g
Original Activity in µCi ^{134}Cs ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1				
2				
3				
4				
7				
15				
21				
29				
57				
91				
119				
147				
183				

APPENDIX 1 (cont'd)

Waste: TURCO 4306 (conc)

Ashland Aropol Wep 661-P
Sample Mass 119.2 g
Original Activity in μCi 11.9 ^{134}Cs 34.0 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	23.3	51.9	8.3×10^{-3}	.16
2	48.1	108.9	1.7×10^{-2}	.51
3	46.6	110.6	1.7×10^{-2}	.85
4	30.5	84.2	1.3×10^{-2}	1.10
7	50.3	109.0	5.9×10^{-3}	1.45
15	113.0	241.4	4.9×10^{-3}	2.22
21	39.8	83.0	2.3×10^{-3}	2.48
29	39.5	82.5	1.7×10^{-3}	2.75
57	100.9	181.2	1.1×10^{-3}	3.37
91	128.5	416.6	1.8×10^{-3}	4.55
119	152.0	595.2	3.0×10^{-3}	6.18
147	503.0	1246.2	6.9×10^{-3}	9.99
183	1489.5	5332.1	2.1×10^{-2}	24.85
366	439.0	2146.8	1.6×10^{-3}	30.49
633	2796.	3210.	2.5×10^{-3}	43.57
730	53.1	1100.7	1.3×10^{-3}	46.09

Dow Waste Binder 101
Sample Mass 120.2 g
Original Activity in μCi 10.4 ^{134}Cs 29.8 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	24.1	89.5	1.4×10^{-2}	.28
2	6.3	16.7	2.9×10^{-3}	.34
3	5.6	15.4	2.7×10^{-3}	.39
4	5.1	16.8	6.9×10^{-4}	.45
7	14.8	44.9	2.5×10^{-3}	.60
15	24.9	84.6	1.7×10^{-3}	.87
21	8.6	45.3	1.1×10^{-3}	1.00
29	11.4	37.9	7.8×10^{-4}	1.12
57	23.7	64.6	4.0×10^{-4}	1.34
91	16.3	75.5	3.4×10^{-4}	1.57
119	11.5	41.6	2.4×10^{-4}	1.70
147	14.1	31.5	2.1×10^{-4}	1.82
183	51.2	132.3	6.5×10^{-4}	2.27
366	20.4	113.3	9.3×10^{-5}	2.61
633	67.4	164.5	1.1×10^{-4}	3.18
730	12.1	31.5	5.7×10^{-5}	3.29

APPENDIX 1 (cont'd)

Waste: PEROXCIT (conc)

Ashland Aropol Wep 661-P
Sample Mass 103.2 g
Original Activity in µCi 14.5 ^{134}Cs 35.6 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	21.9	77.5	1.0×10^{-2}	.20
2	2.7	4.9	7.7×10^{-4}	.21
3	3.3	2.8	6.2×10^{-4}	.23
4	0.8	2.1	2.9×10^{-4}	.23
7	1.7	1.9	1.2×10^{-4}	.24
15	6.1	8.1	1.8×10^{-4}	.27
21	2.3	1.7	6.8×10^{-5}	.28
29	4.6	8.2	1.6×10^{-4}	.30
57	12.4	20.9	1.2×10^{-4}	.37
91	14.9	41.1	1.7×10^{-4}	.48
119	11.2	32.4	1.6×10^{-4}	.57
147	7.9	25.0	1.2×10^{-4}	.63
183	8.4	11.4	5.6×10^{-5}	.67
366	7.9	4.2	6.7×10^{-6}	.70
633	28.9	14.1	1.6×10^{-5}	.78
730	6.1	6.0	1.3×10^{-5}	.81

Dow Waste Binder 101
Sample Mass g
Original Activity in µCi ^{134}Cs ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1				
2				
3				
4				
7				
15				
21				
29				
57				
91				
119				
147				
183				

APPENDIX 1 (cont'd)

Waste: CALGON (conc)

Ashland Aropol Wep 661-P
Sample Mass 105.4 g
Original Activity in μCi 24.0 ^{134}Cs 56.7 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	4.2	18.1	1.4×10^{-3}	.03
2	1.8	4.8	4.2×10^{-4}	.04
3	1.0	4.1	3.2×10^{-4}	.04
4	0.9	3.8	3.0×10^{-4}	.05
7	5.2	14.2	4.1×10^{-4}	.07
15	16.6	43.0	4.7×10^{-4}	.15
21	6.6	13.4	2.1×10^{-4}	.17
29	6.8	6.8	1.1×10^{-4}	.19
57	20.2	15.6	8.1×10^{-4}	.23
91	27.8	52.5	1.5×10^{-4}	.33
119	15.1	34.6	1.1×10^{-4}	.39
147	9.1	21.8	7.0×10^{-5}	.43
183	8.4	6.7	2.6×10^{-5}	.45
366	15.0	19.6	1.2×10^{-5}	.49
633	40.5	17.2	1.4×10^{-5}	.56
730	6.5	3.0	6.2×10^{-6}	.58

Dow Waste Binder 101
Sample Mass 108.5 g
Original Activity in μCi 21.8 ^{134}Cs 52.6 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	4.2	13.9	1.2×10^{-3}	.02
2	1.3	4.9	4.2×10^{-4}	.03
3	1.9	6.2	5.5×10^{-4}	.04
4	1.6	7.1	5.9×10^{-4}	.06
7	3.7	20.1	5.4×10^{-4}	.09
15	13.4	51.7	5.6×10^{-4}	.17
21	5.7	13.1	2.1×10^{-4}	.20
29	5.7	13.0	1.6×10^{-4}	.22
57	13.4	16.1	7.2×10^{-5}	.26
91	15.8	49.5	1.3×10^{-4}	.35
119	13.2	32.1	1.1×10^{-4}	.41
147	15.3	42.9	1.4×10^{-4}	.49
183	17.0	59.3	1.5×10^{-4}	.59
366	64.8	339.0	1.5×10^{-4}	1.14
633	130.9	231.0	9.3×10^{-4}	1.62
730	53.4	100.4	1.1×10^{-4}	1.83

APPENDIX 1 (cont'd)

Waste: PICKERING SOLUTION (conc)

Ashland Aropol Wep 661-P
Sample Mass 103.9 g
Original Activity in μCi 16.6 ^{134}Cs 40.0 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	19.1	77.5	8.7×10^{-3}	.17
2	3.1	7.6	9.6×10^{-4}	.19
3	2.0	2.8	4.3×10^{-4}	.20
4	1.2	3.6	4.3×10^{-4}	.21
7	6.6	13.2	5.9×10^{-4}	.24
15	30.3	70.0	1.1×10^{-3}	.42
21	23.8	52.4	1.1×10^{-3}	.55
29	24.6	56.0	9.1×10^{-4}	.70
57	56.0	139.5	6.3×10^{-4}	1.04
91	29.8	100.3	3.4×10^{-4}	1.27
119	16.9	58.7	2.4×10^{-4}	1.40
147	12.3	50.9	2.0×10^{-4}	1.52
183	14.9	49.1	1.6×10^{-4}	1.63
366	35.6	179.8	1.1×10^{-4}	2.01
633	104.2	222.3	1.1×10^{-4}	2.59
730	17.7	54.1	6.7×10^{-5}	2.71

Dow Waste Binder 101
Sample Mass 84.0 g
Original Activity in μCi 16.3 ^{134}Cs 38.9 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	1.8	2.8	4.2×10^{-4}	.01
2	54.4	101.0	1.4×10^{-2}	.29
3	2175.0	7250.0	8.7×10^{-1}	17.36
4	944.0	3096.0	3.7×10^{-1}	24.68
7	1292.0	4018.0	1.6×10^{-1}	34.30
15	1285.0	4519.0	6.7×10^{-2}	44.82
21	477.0	1390.0	2.9×10^{-2}	48.20
29	479.0	1347.0	2.1×10^{-2}	51.51
57	667.0	1964.0	8.7×10^{-3}	56.27
91	384.0	1650.0	5.5×10^{-3}	59.96
119	101.0	1149.0	4.1×10^{-3}	62.22
147	179.0	958.0	3.7×10^{-3}	64.28
183	873.0	4268.0	1.3×10^{-2}	73.59
366	168.1	1587.2	8.6×10^{-4}	76.77
633	366.	967.	4.6×10^{-4}	79.19
730	57.4	226.3	2.7×10^{-4}	79.70

APPENDIX 1 (cont'd)

Waste: STPP (conc)

Ashland Aropol Wep 661-P
Sample Mass 107.2 g
Original Activity in μCi 19.0 ^{134}Cs 55.5 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d^{-1}	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	37.4	94.7	9.0×10^{-3}	.18
2	60.8	142.7	1.4×10^{-2}	.45
3	29.1	99.3	8.8×10^{-3}	.62
4	25.7	91.8	8.0×10^{-3}	.78
7	66.2	176.1	5.5×10^{-3}	1.11
15	60.3	164.2	1.9×10^{-3}	1.41
21	45.9	105.4	1.7×10^{-3}	1.61
29	61.7	146.3	1.8×10^{-3}	1.89
57	112.4	296.4	1.0×10^{-3}	2.44
91	67.1	159.9	4.6×10^{-4}	2.74
119	23.9	119.5	3.5×10^{-4}	2.94
147	13.6	53.9	1.6×10^{-4}	3.03
183	12.0	52.1	1.2×10^{-4}	3.11
366	42.8	120.3	6.1×10^{-5}	3.33
633	199.5	240.3	1.1×10^{-4}	3.92
730	44.6	43.2	6.2×10^{-5}	4.04

Dow Waste Binder 101
Sample Mass 107.1g
Original Activity in μCi 18.9 ^{134}Cs 56.6 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d^{-1}	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	9.5	33.7	2.9×10^{-3}	.06
2	4.4	12.5	1.1×10^{-3}	.08
3	1.4	19.0	1.4×10^{-3}	.11
4	4.6	15.5	1.4×10^{-3}	.13
7	6.2	30.7	8.3×10^{-4}	.18
15	16.2	46.3	5.3×10^{-4}	.26
21	15.7	38.3	6.1×10^{-4}	.34
29	20.8	50.8	6.0×10^{-4}	.43
57	55.5	167.7	5.4×10^{-4}	.73
91	53.9	220.8	5.5×10^{-4}	1.09
119	32.8	150.7	4.4×10^{-4}	1.33
147	14.9	123.5	3.3×10^{-4}	1.52
183	13.8	113.7	2.4×10^{-4}	1.69
366	44.8	298.7	1.3×10^{-4}	2.14
633	158.3	376.4	1.4×10^{-4}	2.85
730	25.6	41.3	4.7×10^{-5}	2.93

APPENDIX 1 (cont'd)

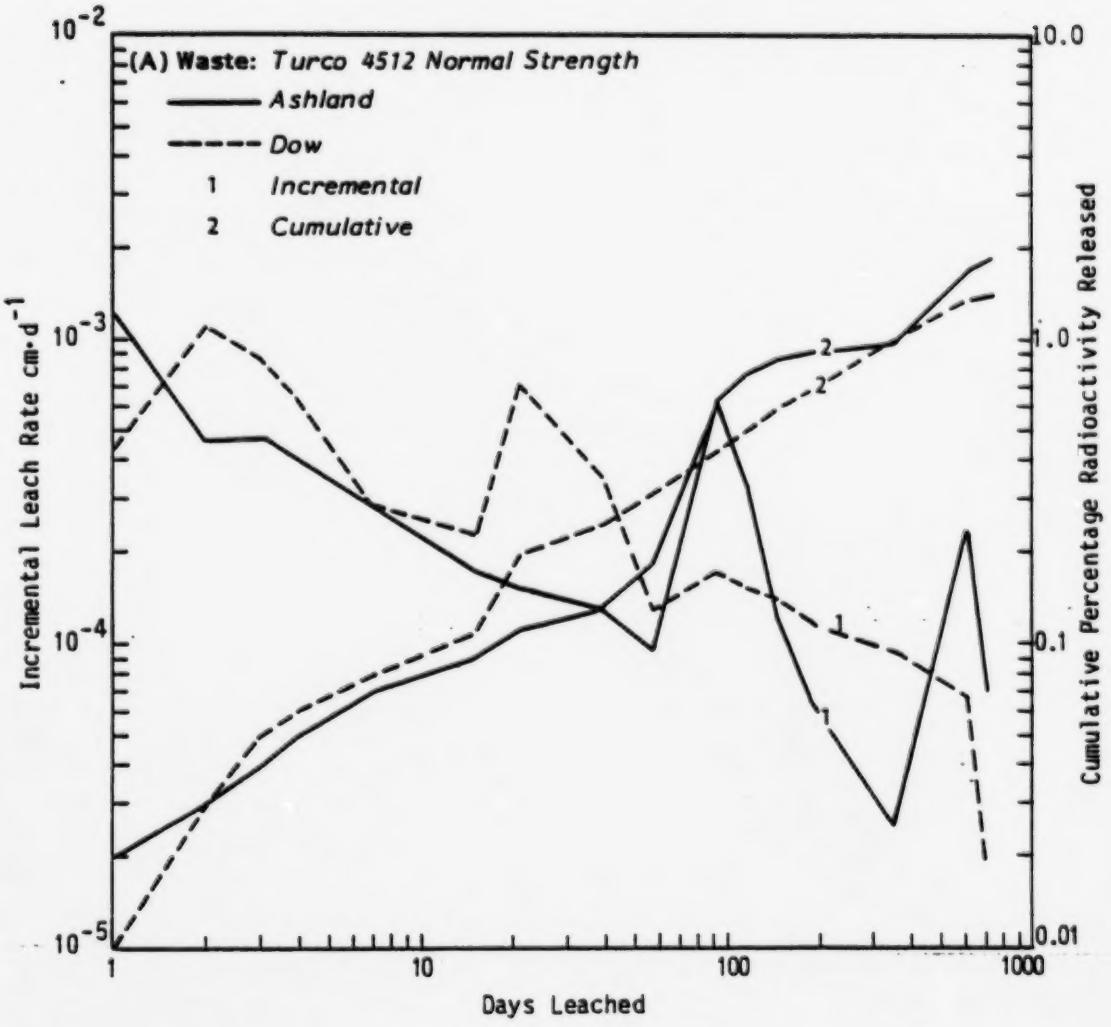
Waste: PEROXIDE BICARBONATE (conc)

Ashland Aropol Wep 661-P
Sample Mass 108.6 g
Original Activity in µCi 12.5 ^{134}Cs 42.6 ^{60}Co

Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1	107.0	70.8	1.6×10^{-2}	.32
2	75.3	88.4	1.5×10^{-2}	.62
3	50.6	125.3	1.6×10^{-2}	.94
4	67.4	75.4	1.3×10^{-2}	1.20
7	244.8	126.8	1.1×10^{-2}	1.87
15	784.0	622.0	1.6×10^{-2}	4.42
21	496.0	478.0	1.5×10^{-2}	6.19
29	496.0	920.0	1.6×10^{-2}	8.76
57	1107.6	821.5	6.4×10^{-3}	12.26
91	743.5	839.5	4.3×10^{-3}	15.14
119	521.8	560.8	3.6×10^{-3}	17.10
147	95.2	124.4	7.3×10^{-4}	17.50
183	292.3	235.5	1.4×10^{-3}	18.46
366	330.5	446.9	3.9×10^{-4}	19.87
633	441.2	358.5	2.8×10^{-4}	21.32
730	76.8	133.3	2.0×10^{-4}	21.70

Dow Waste Binder 101
Sample Mass g
Original Activity in µCi ^{134}Cs ^{60}Co

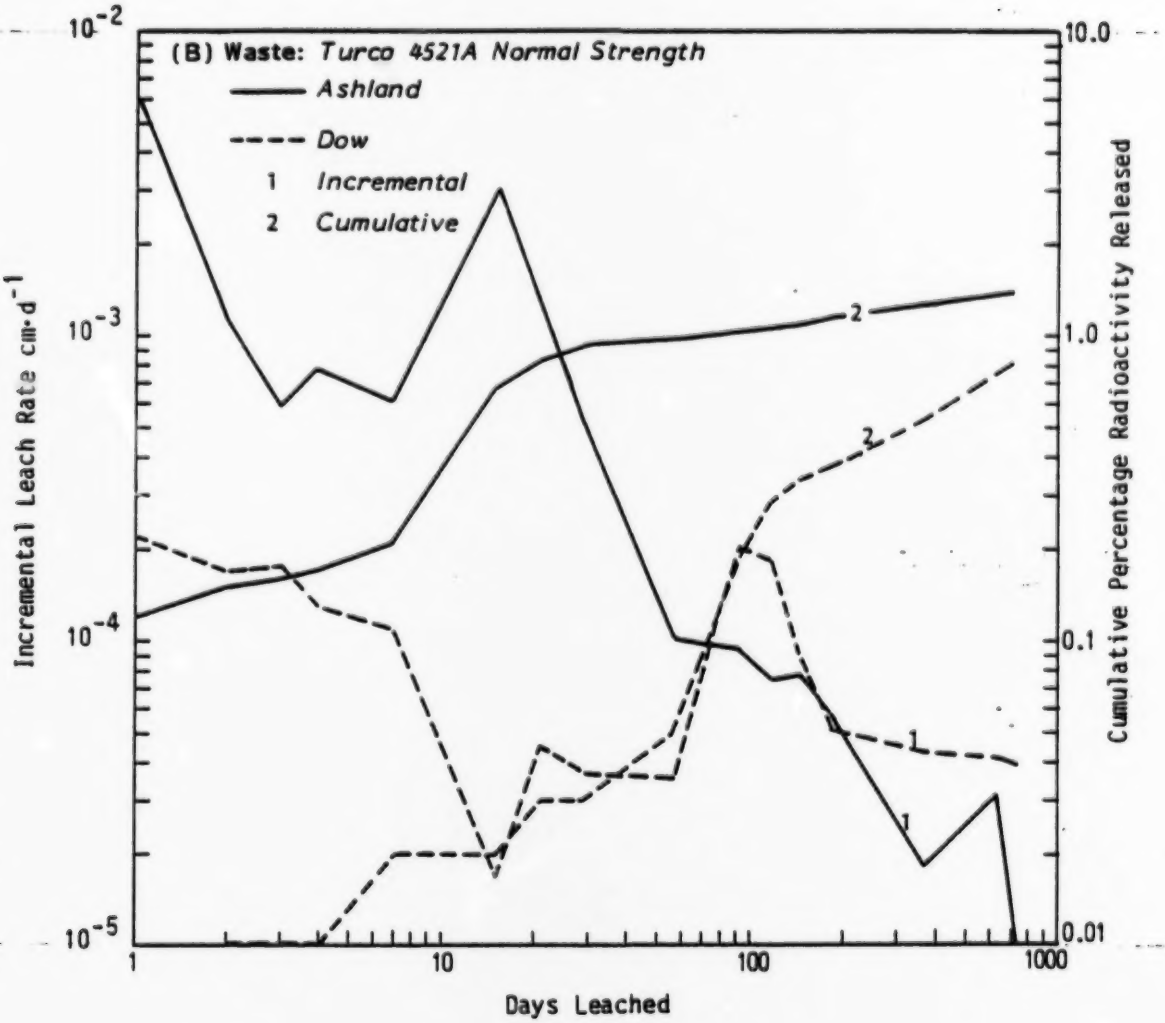
Days	Incremental Releases nCi		Incremental Leach Rate cm·d-1	Cumulative Releases %
	^{134}Cs	^{60}Co		
1				
2				
3				
4				
7				
15				
21				
29				
57				
91				
119				
147				
183				



APPENDIX 2

LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS

152424 RD



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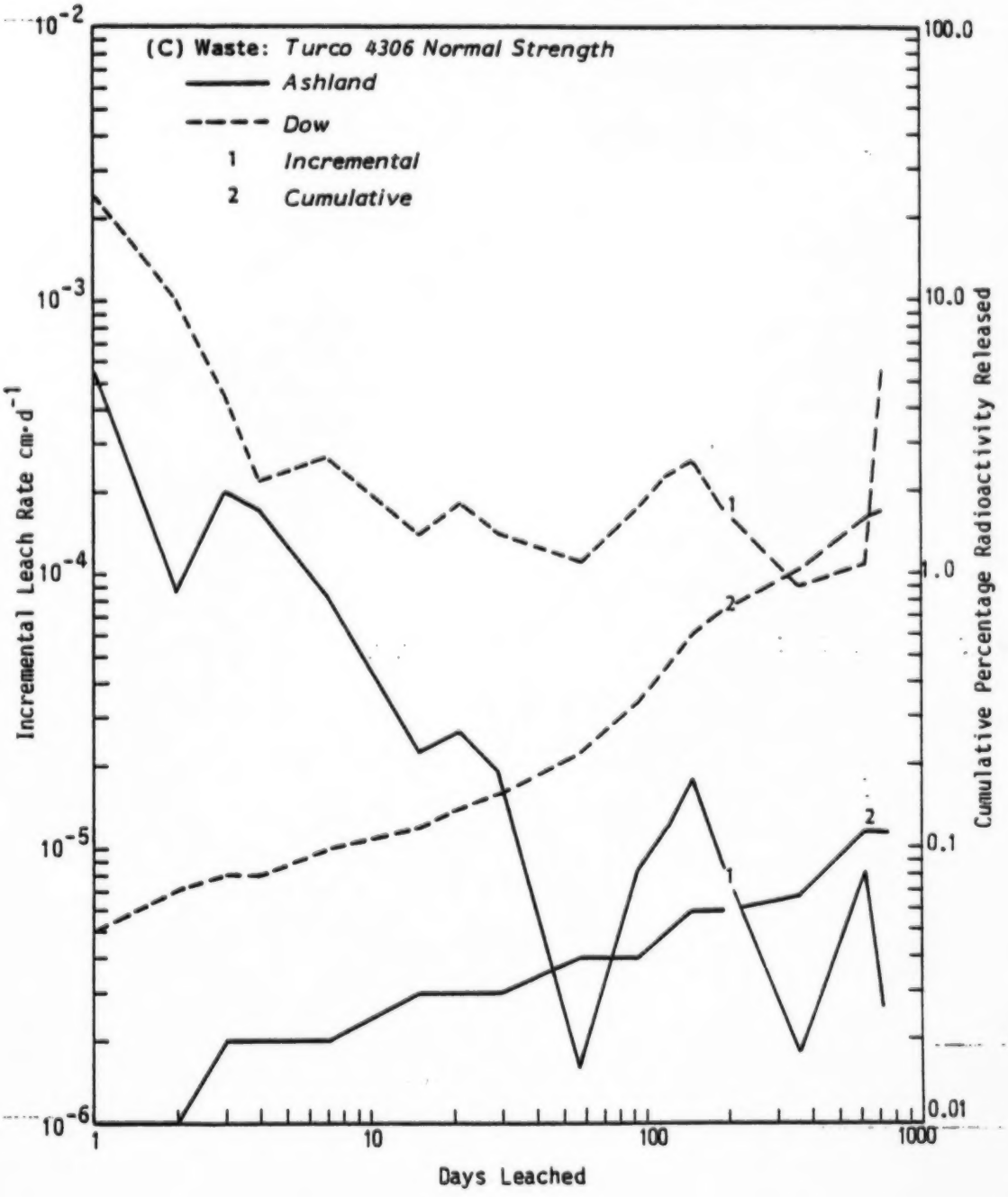
LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS

152425 RD



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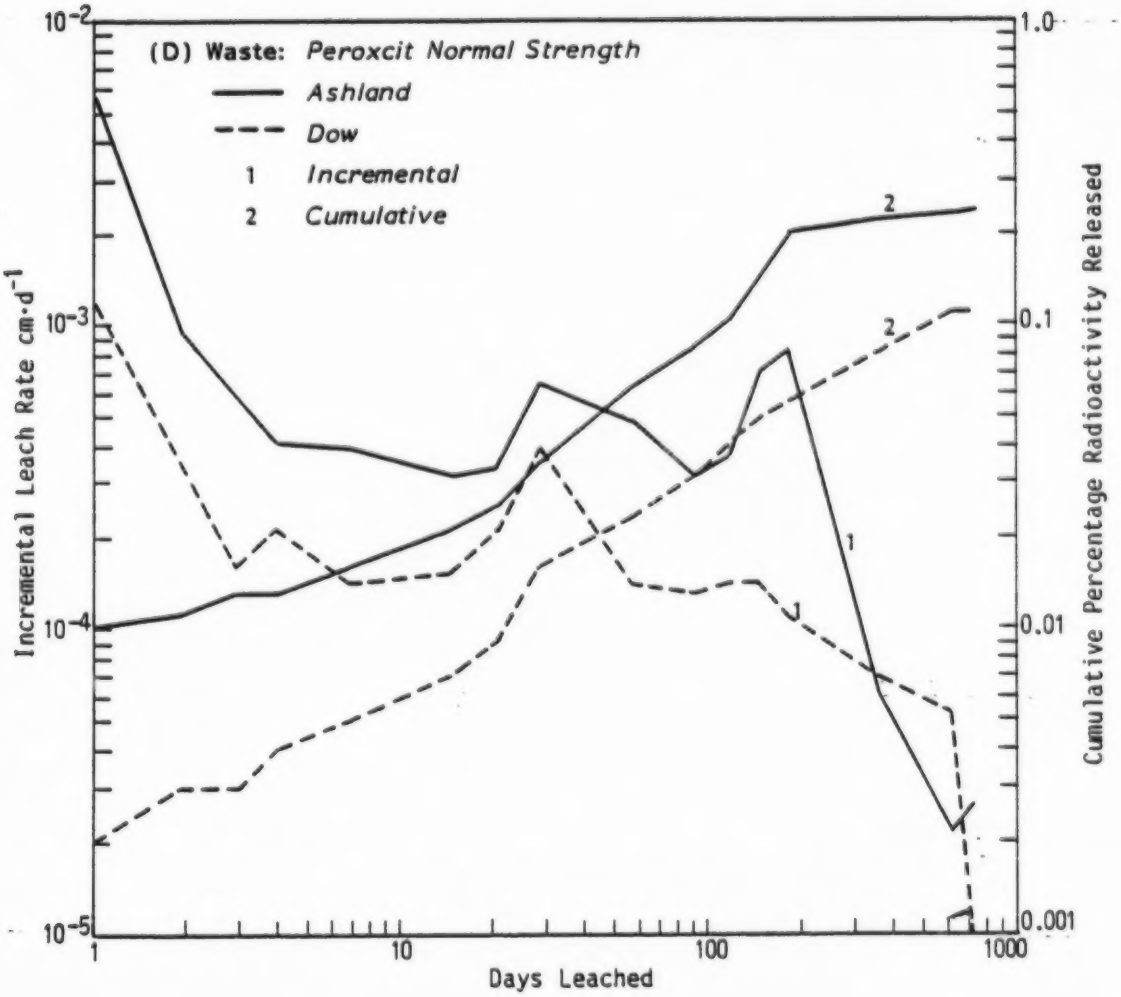
LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS

152426 RD



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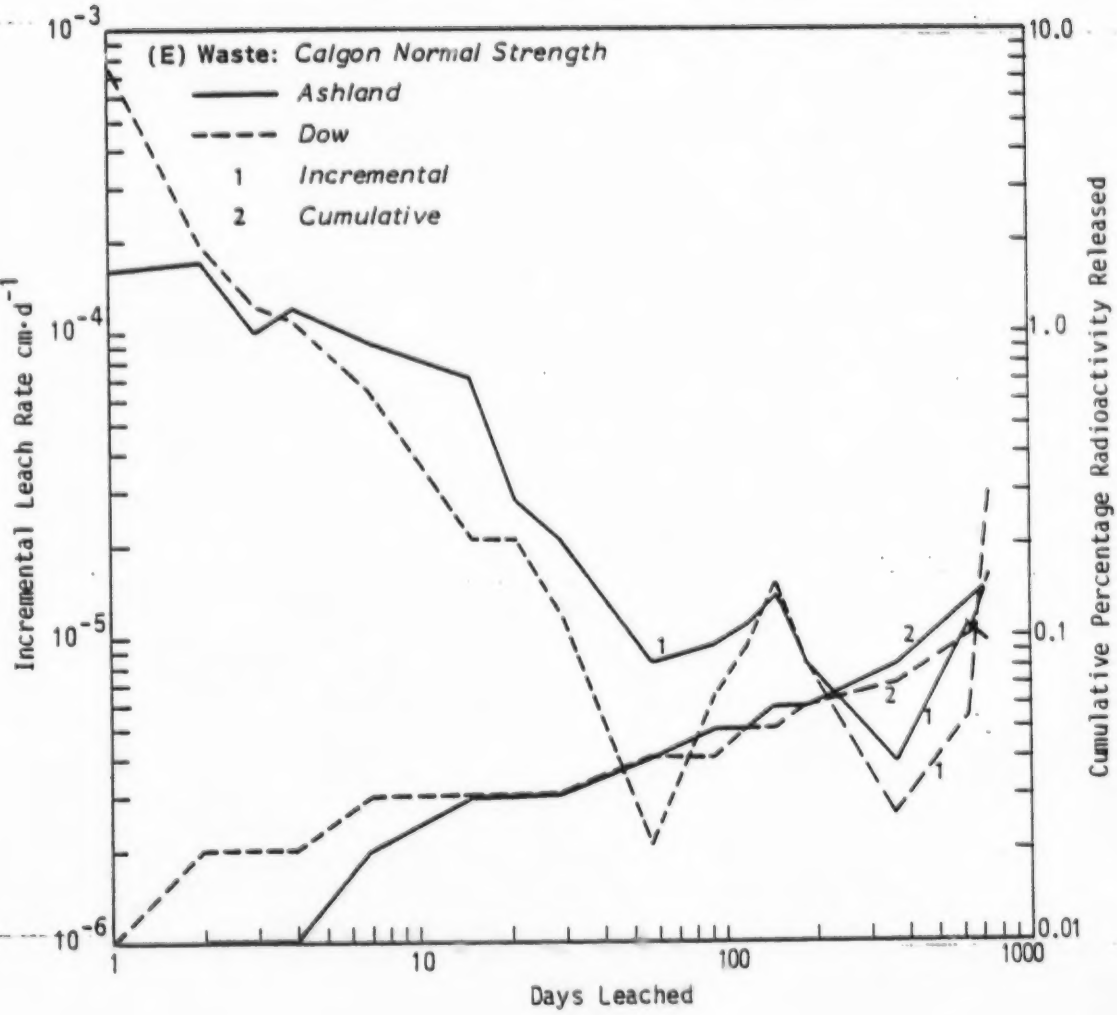

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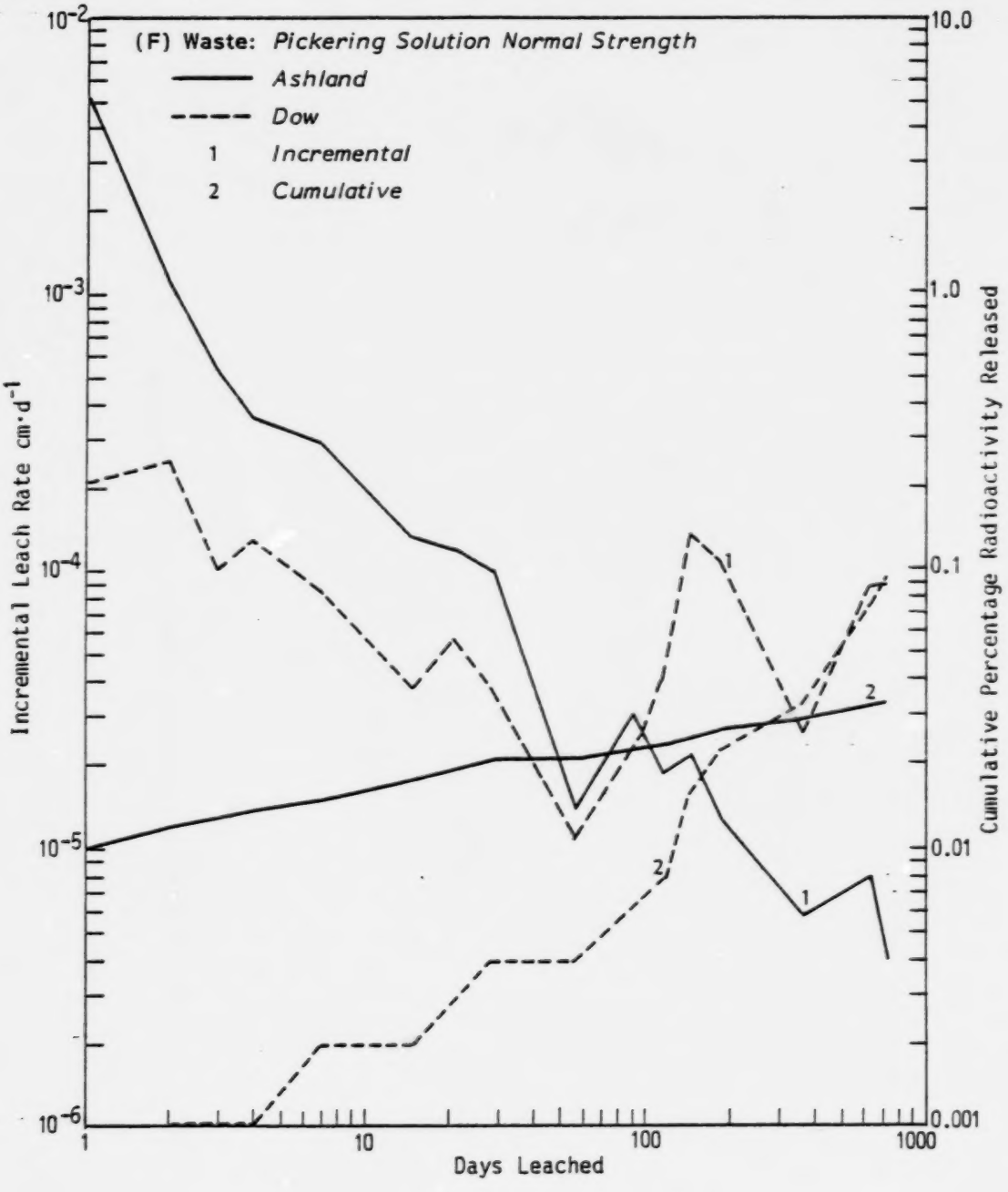
LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS

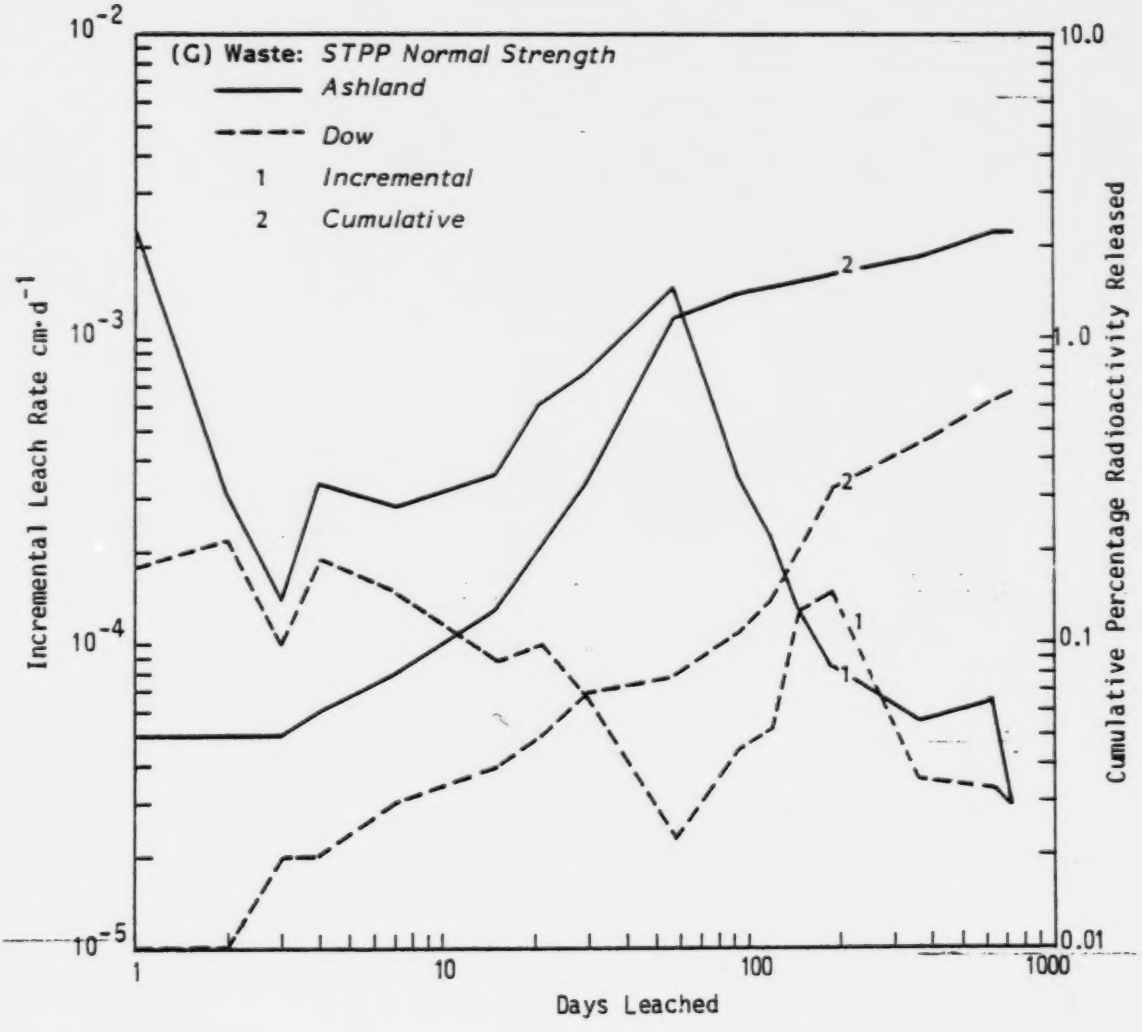
152428 RD



APPENDIX 2

LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION WASTES

152429 RD



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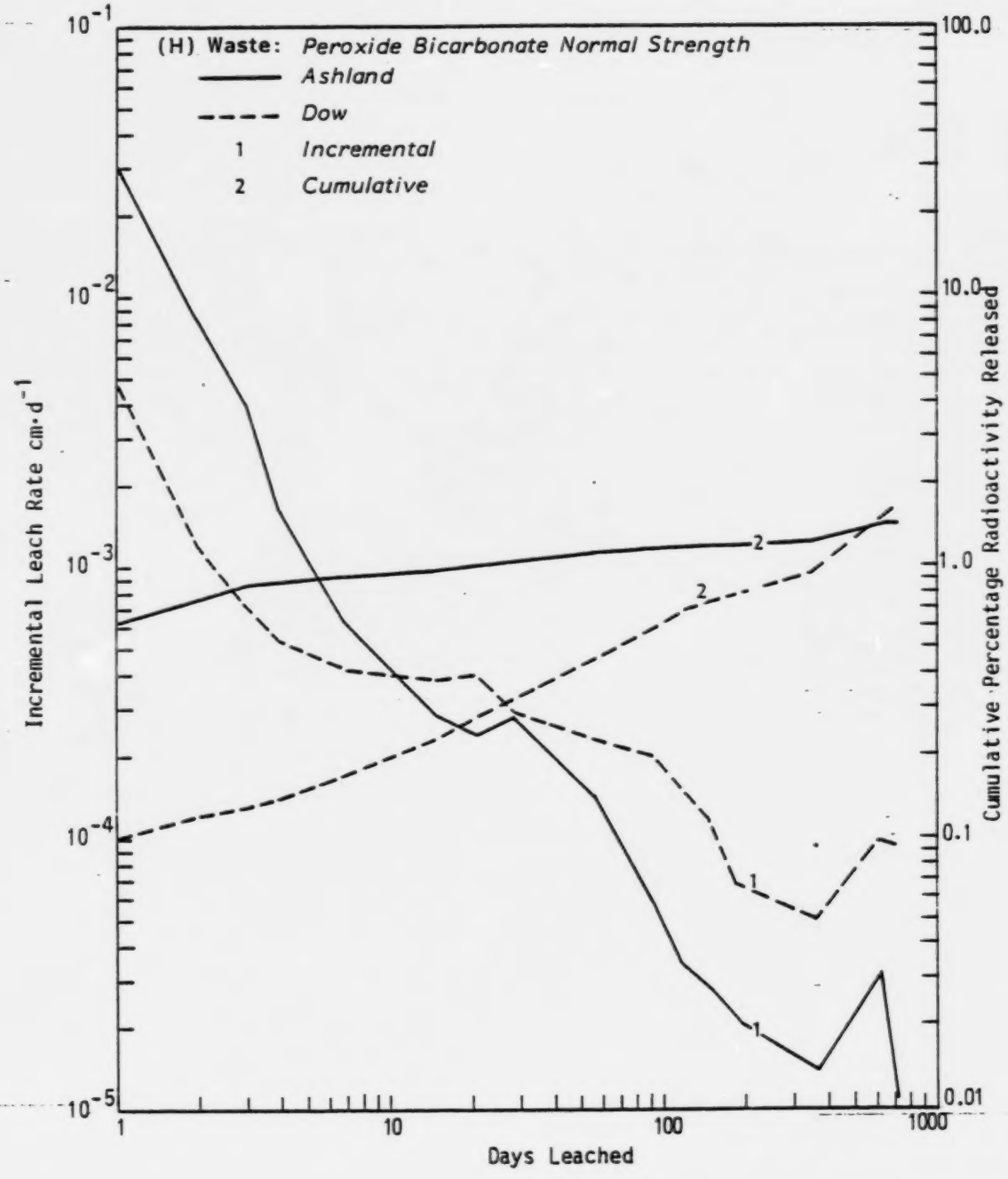
152430 RD



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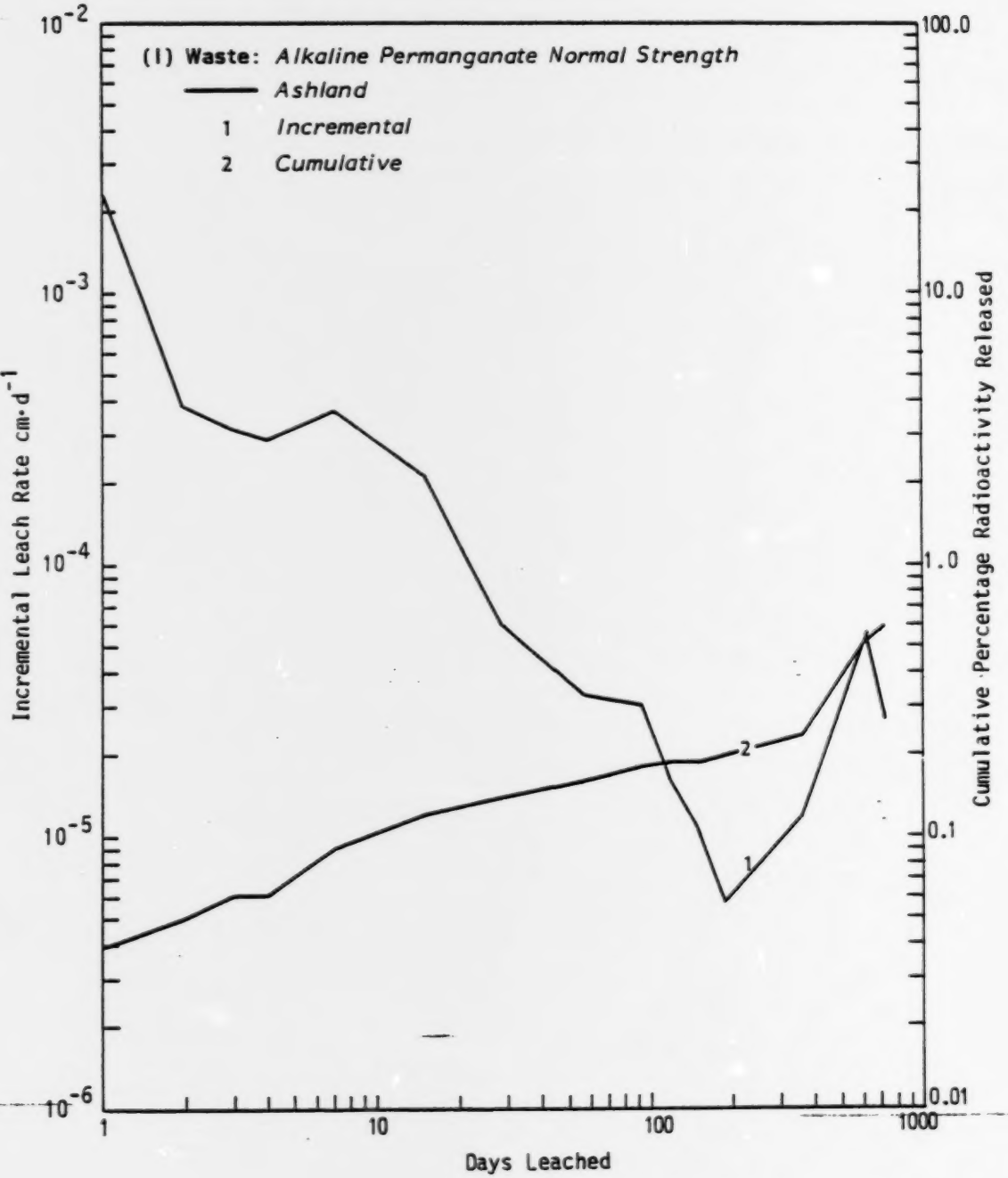
LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS

152431 RD



APPENDIX 2

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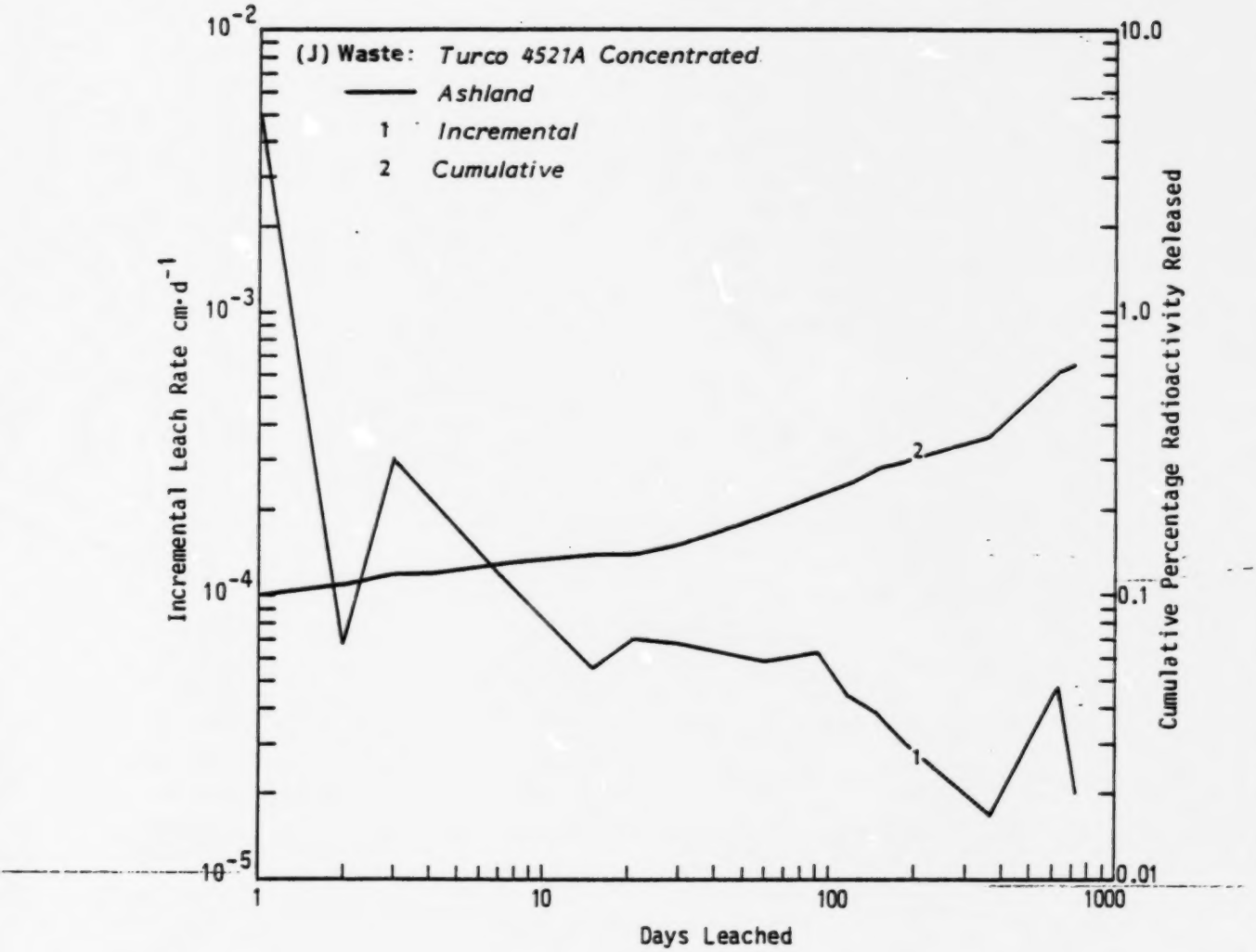
152432 RD



APPENDIX 2

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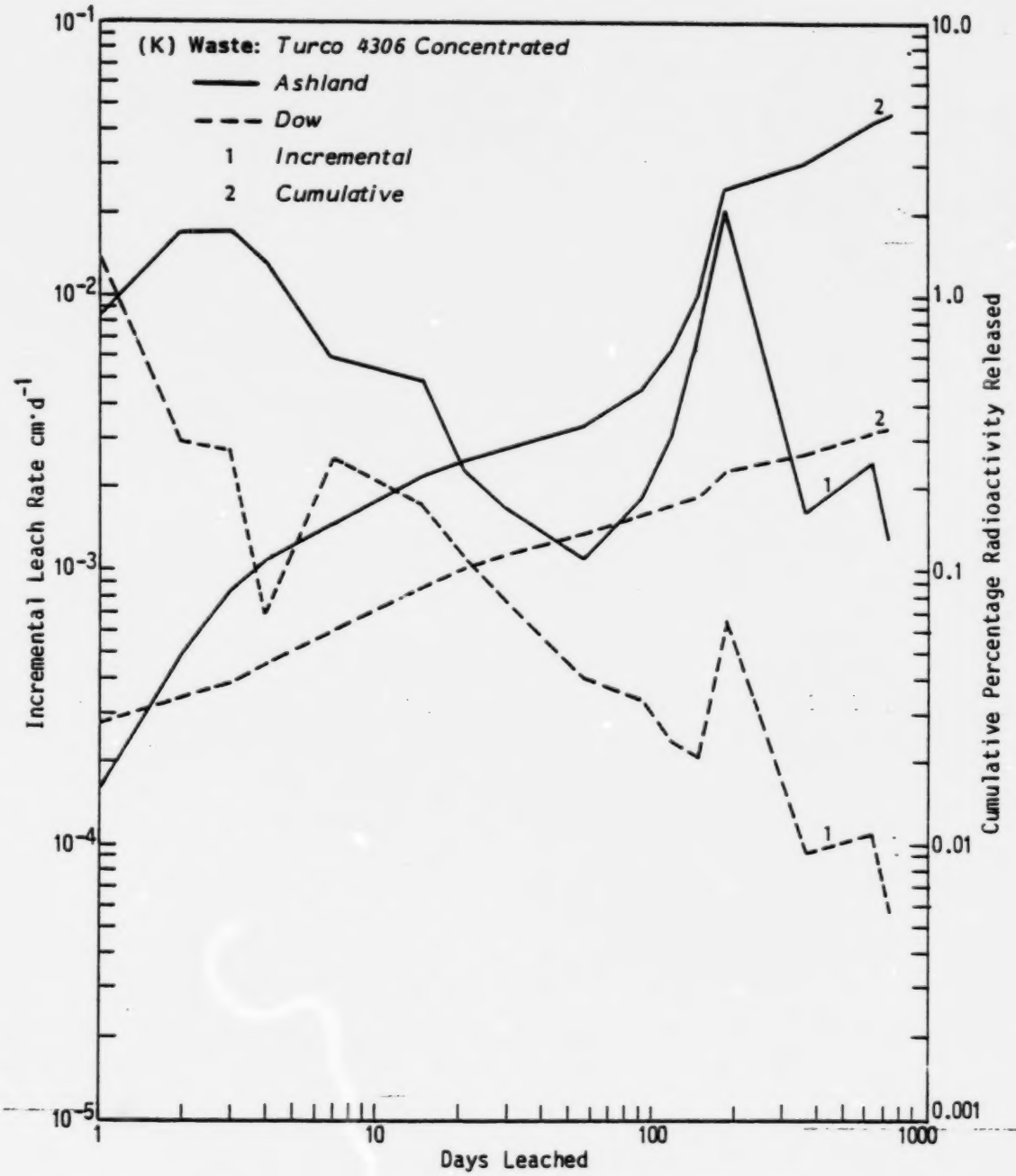
152433 RD



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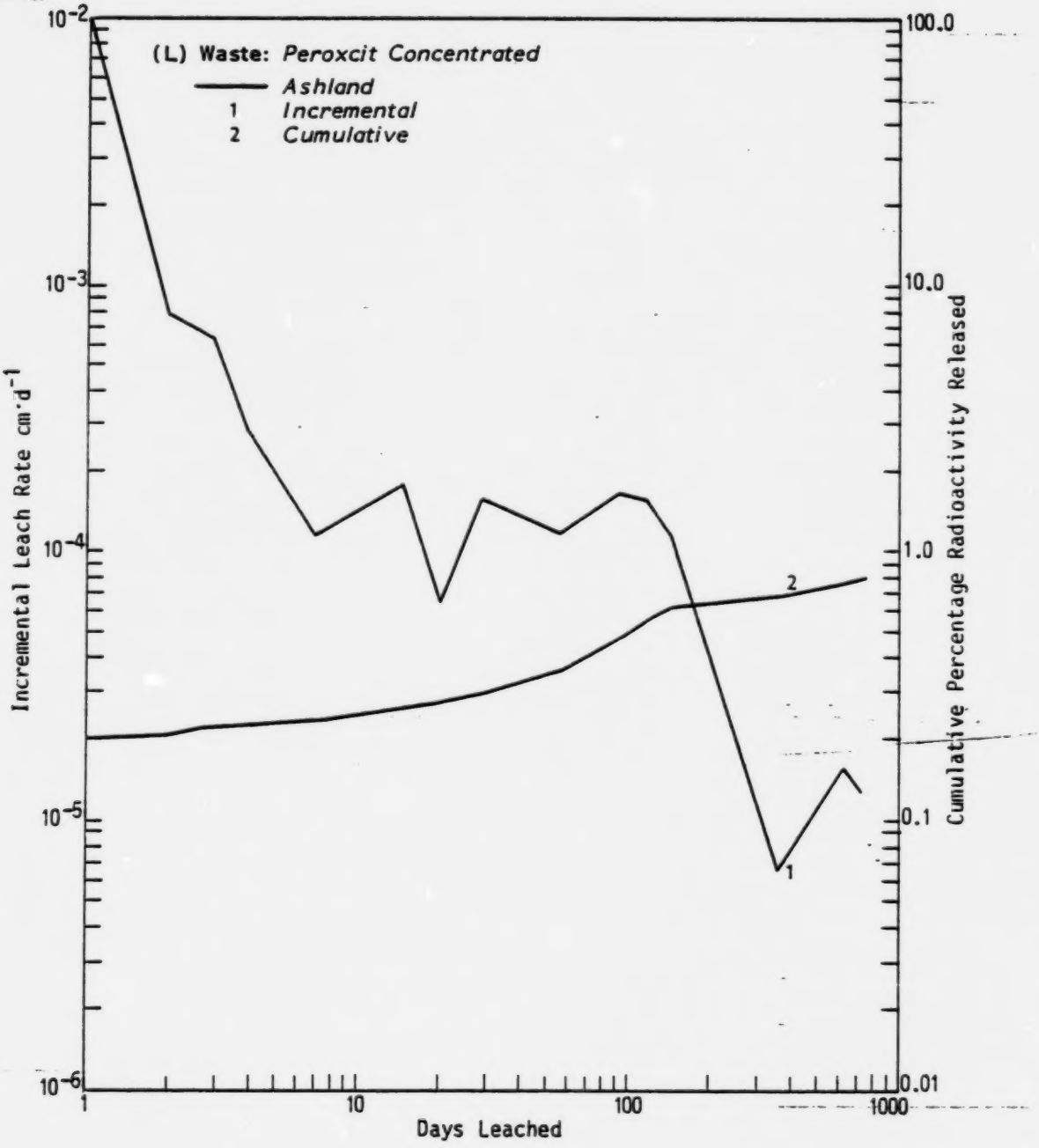

APPENDIX 2

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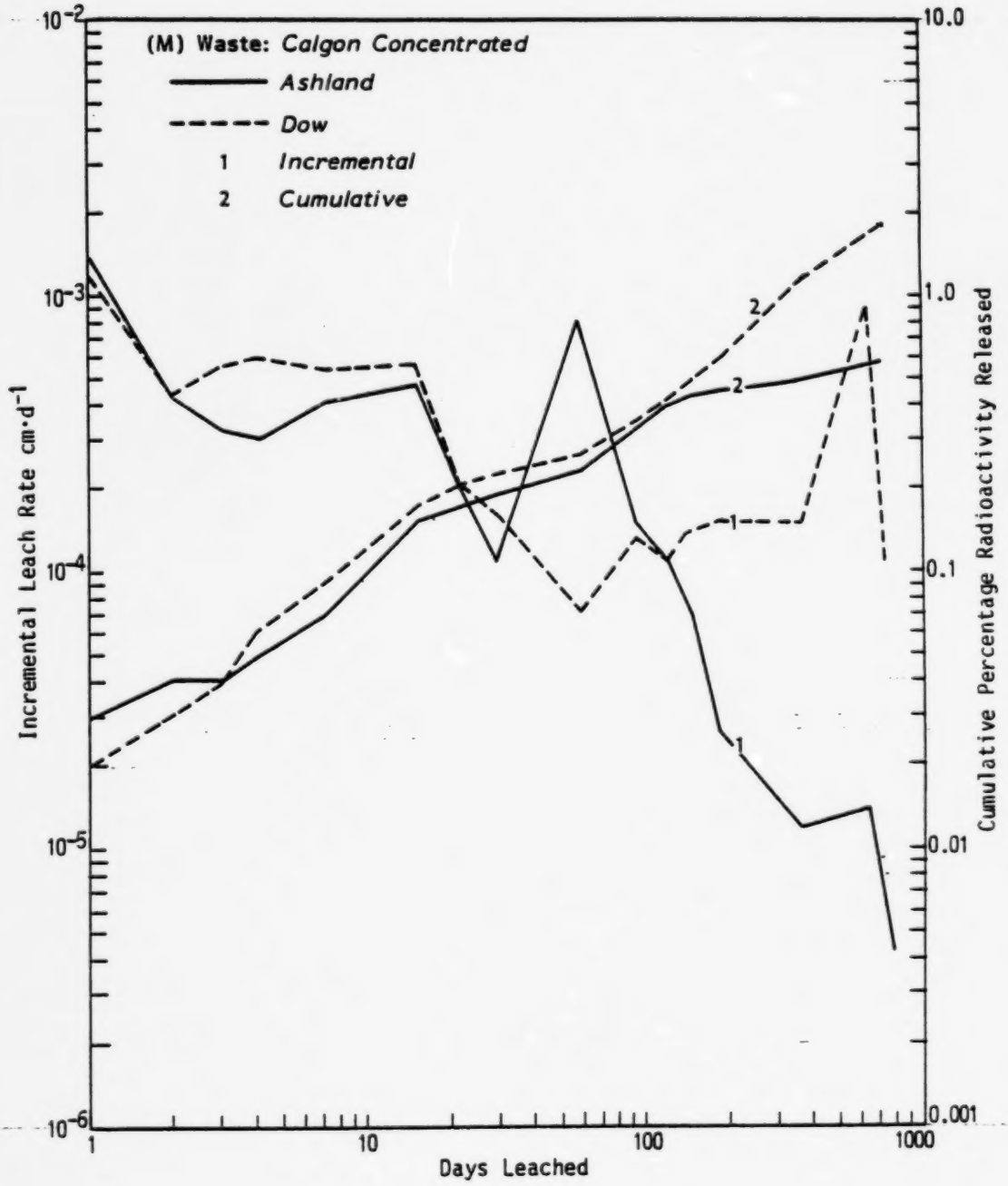

APPENDIX 2

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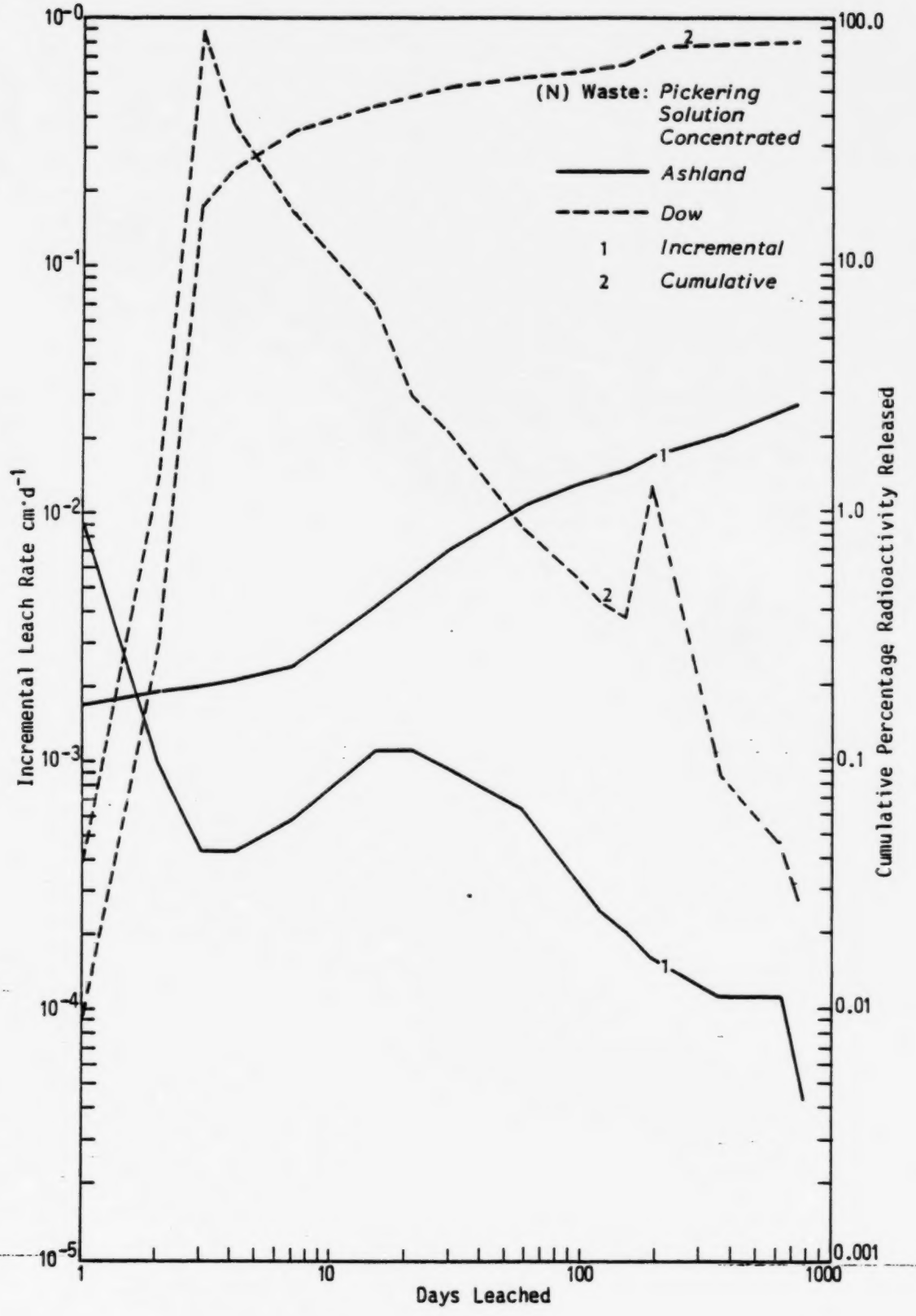
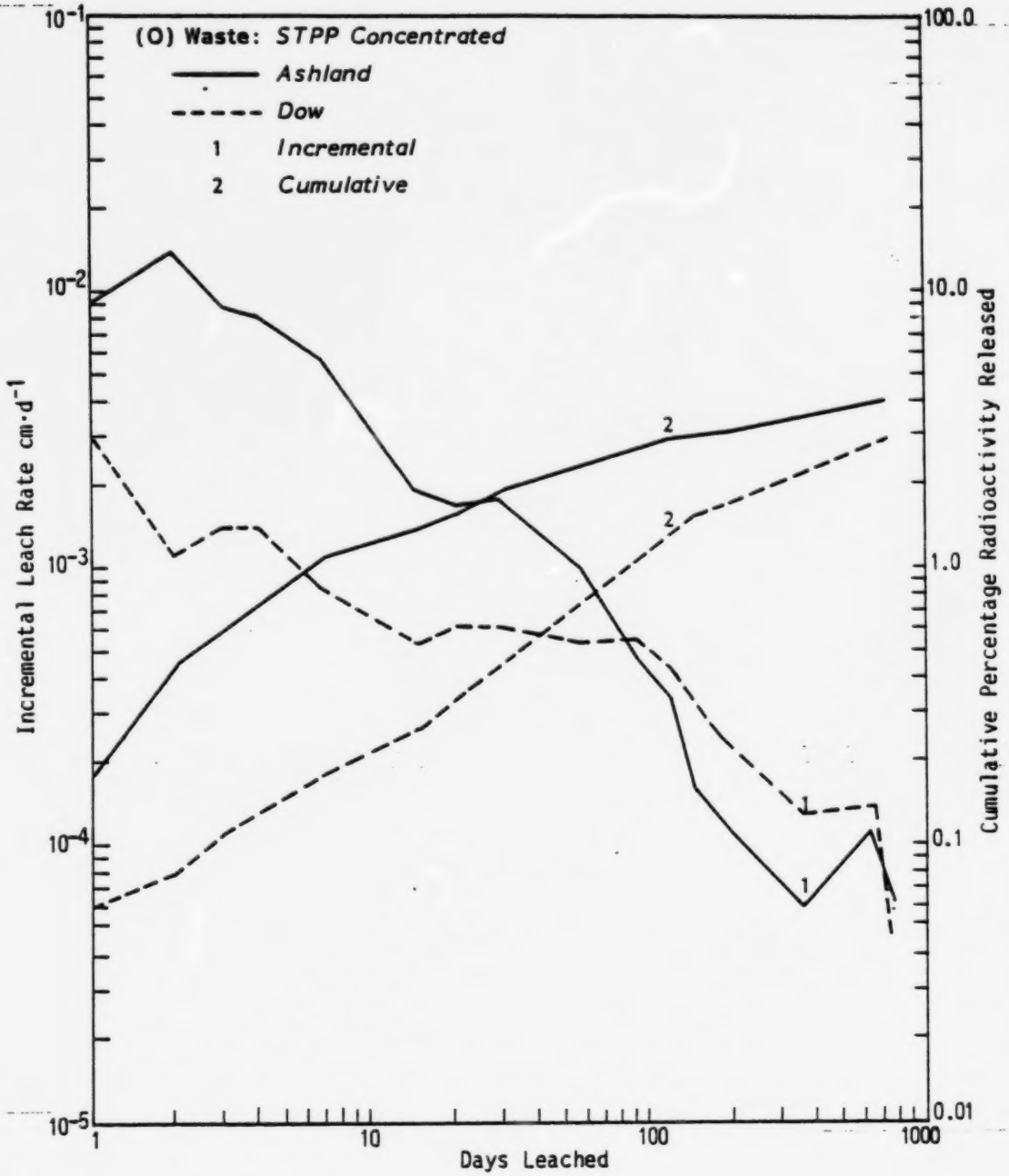


APPENDIX 2

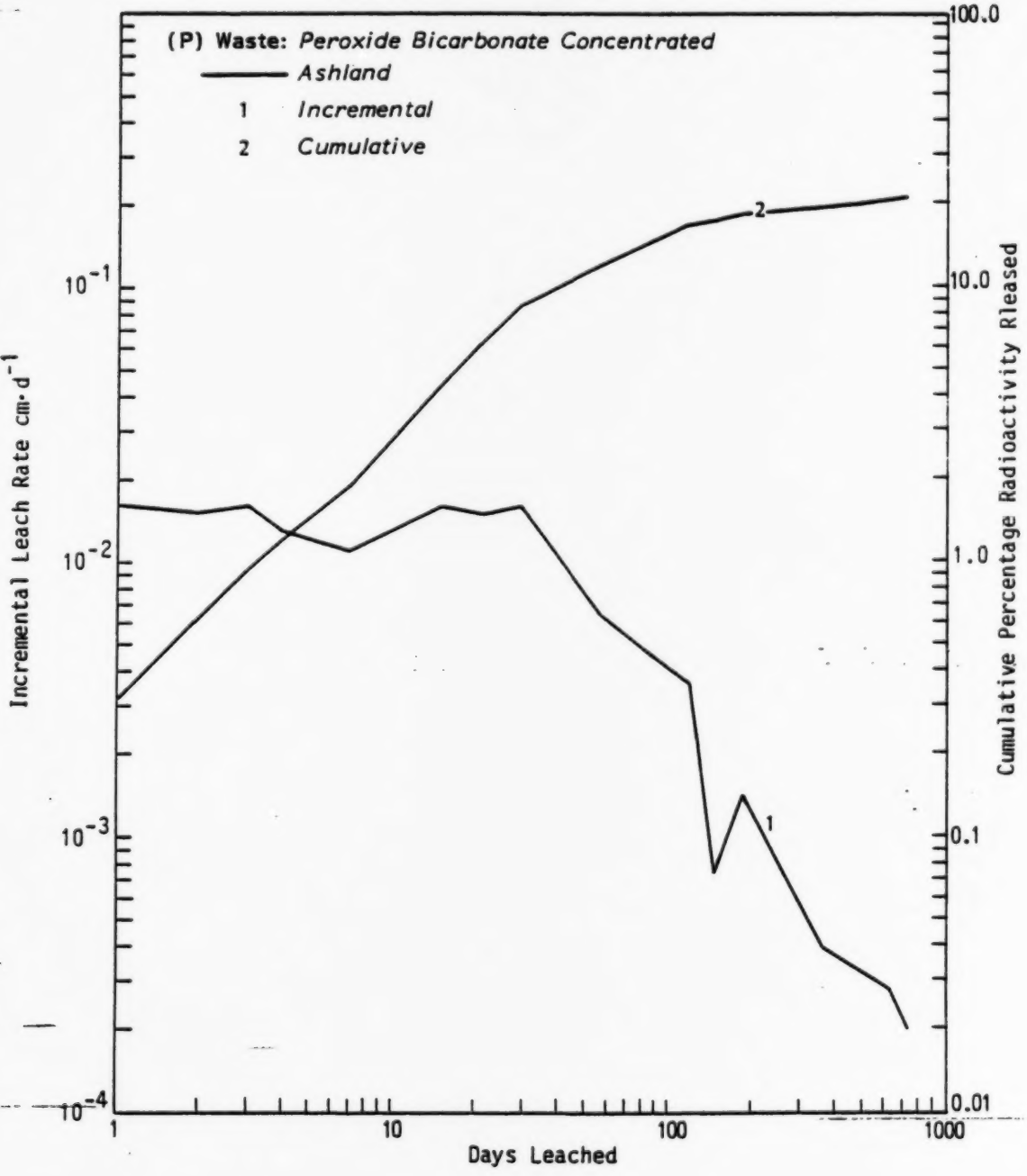
LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS

152439 RD



APPENDIX 2

LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS



APPENDIX 2

LEACHING RESISTANCE OF SOLIDIFIED DECONTAMINATION SOLUTIONS

152438 RD

APPENDIX 3

SIMULATED DECONTAMINATION SOLUTION COMPOSITIONS

Name	Chemical	Use Conc g/kg	High Conc g/kg
Turco 4512	phosphoric acid	50	—
Turco 4521A	ammonium citrate 66% oxalic acid 34%	50	400
Turco 4306	sulphamic acid	50	400
Peroxcit	oxalic acid citric acid hydrogen peroxide	93	400
Calgon	sodium hexametaphosphate	10	100
Nacconal	detergent	10	—
Pickering Solution	sod hexametaphosphate 50% Nacconal 25% EDTA 25%	10	100
STPP	sod tripolyphosphate	10	100
Peroxide Bicarbonate	sodium carbonate 57% sodium bicarbonate 27% hydrogen peroxide 16%	127	450
Alkaline Permanganate	sodium hydroxide 77% potassium permanganate 23%	130	—

POOR

QUALITY

ORIGINAL